2023 COASTAL MASTER PLAN

RESTORATION IMPACTS ON SURGE AND RISK – BARATARIA BARRIER ISLANDS

SUPPLEMENTAL MATERIAL H6.6

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COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

CITATION

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LIST OF ABBREVIATIONS

ADCIRC .... ADVANCED CIRCULATION MODEL
CPRA................................COASTAL PROTECTION AND RESTORATION AUTHORITY
DEM...DIGITAL ELEVATION MODEL
FT.. FEET
FWOA..FUTURE WITHOUT ACTION
HSDRRS .... HURRICANE AND STORM DAMAGE RISK REDUCTION SYSTEM
ICM-BI ....INTEGRATED COMPARTMENT MODEL – BARRIER ISLANDS
KTS .... KNOTS
M...METERS
MB...MILLIBARS
MI .... MILES
NAVD88... NORTH AMERICAN VERTICAL DATUM OF 1988
SLR..SEA LEVEL RISE
SWAN .... SIMULATING WAVES NEARSHORE MODEL

1.0 INTRODUCTION

The degraded barriers exploratory analysis evaluates coastal flood trends for a future without action (FWOA) in which only barrier islands experience restoration over time, and a FWOA in which barriers are not restored and are allowed to degrade, limiting their subaerial footprint. Barriers as defined for this analysis are comprised of a series of interlinked features including barrier islands, barrier spits, and headlands. Tidal inlets, typically found between two adjacent barrier islands, are an essential component of the barrier and overall estuarine system by facilitating water, sediment, and nutrient exchange between the backbarrier environment and coastal ocean (FitzGerald & Miner, 2013; Ranasinghe et al., 2013). Inlet size is controlled by tidal currents that remove wave-deposited sand and lead to the development of ebb- and flood- deltas seaward and landward of the inlet throat, respectively (FitzGerald et al., 1984; Hayes, 1980). The volume of water that moves through the inlet over a tidal cycle is called the tidal prism, while the tidal range is the vertical difference between high and low tide. During storms, the surge from the shelf enters the backbarrier bays through tidal inlets, gradually inundating the backbarrier landscape. With the continued increase of surge heights near barrier islands, barriers are gradually inundated, and eventually overtopped when surge heights exceed the dune crest elevation on the barrier island. During this time, there is increased conveyance, and flow through the inlets and across the barrier island platform increases, facilitating an additional increase in inland surge heights and flooding.

This document describes the simulation modeling and corresponding analysis results without and with degraded barriers, to evaluate the potential increase in coastal flooding risk that would occur along coastline that has not received restoration or nourishment. Eight individual storms were selected from a larger storm suite of synthetic storms developed for Louisiana's 2023 Coastal Master Plan and used to evaluate coastal flood risk for future conditions at Year 20. The simulated storms (66, 88, 178, 268, 289, 395, 505, and 590; Figure 1) were selected based on their respective tracks, approach angles and landfall locations, and their potential to influence surge heights within the Barataria Basin to the east along the levees from New Orleans to Venice, and to the west along levees from Larose, LA to Golden Meadow, LA. The storms investigated had various headings (from 300 to 40 degrees), forward speeds (from approximately 6 – 16 knots [kts]), and size (radius to maximum winds from 16 – 44 miles [mi]). The Advanced Circulation (ADCIRC) and Simulating Waves Nearshore (SWAN) models were used to simulate surge and wave heights for each of the eight synthetic storms analyzed. Prior to the 2023 Coastal Master Plan, an extensive model validation and calibration study was conducted by Cobell and Roberts (2021) to ensure that the parameters used within the model were most appropriate from those currently found within the modeling community and available literature.

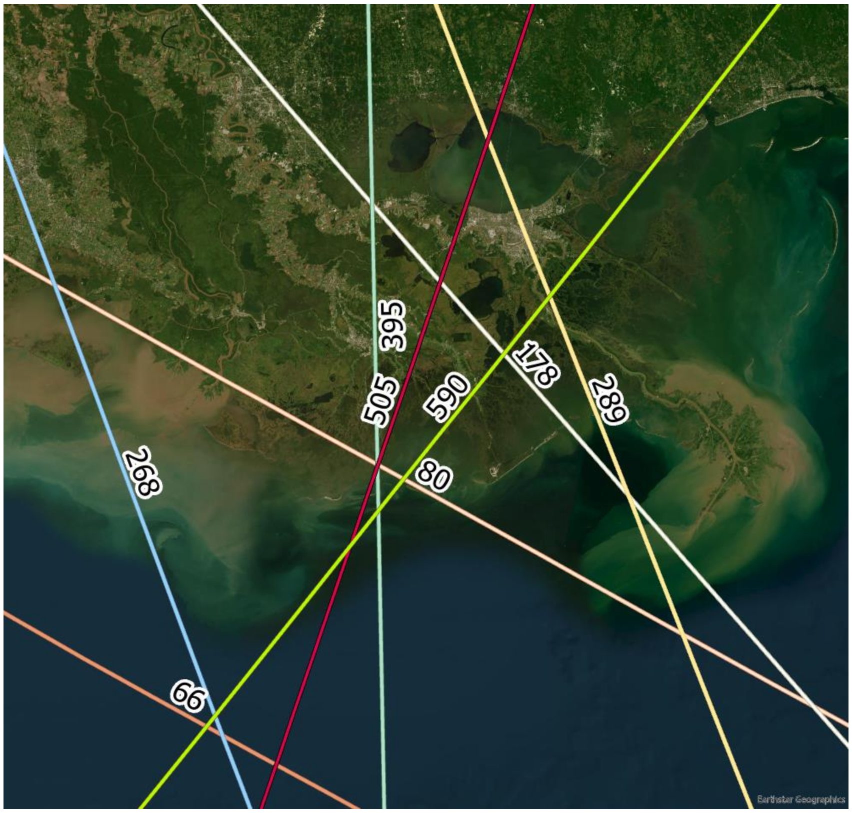

Figure 1. Storm tracks for the synthetic storms used to evaluate the coastal flooding risk for the degraded barriers exploratory analysis. Storm headings range from southwest (~300 degrees) to northeast (~40 degrees).

2.0 METHODOLOGY

Barrier islands identified in this analysis at Year 20 using the lower sea level rise (SLR) environmental scenario (S07; "lower scenario") included Fourchon Beach along the Caminada Headland and Elmer's Island, West Belle Pass, and the barrier islands fronting the Barataria Basin, including West Grand Terre, East Grand Terre, Grand Pierre, Chaland, Shell Island, Pelican Island and Scofield Island (Figure 2). The approach leveraged output from [Attachment C9: 2023 Barrier Islands Model: ICM-BITI and ICM-BI] (Dalyander et al., 2021) for the selected lower scenario for Year 20. The ICM-BI output was additionally modified to further degrade the barriers by modifying the sub-tidal geomorphic features (e.g., sand shoals and nearshore bars), and supratidal and dune habitats to ensure loss of barrier relief.

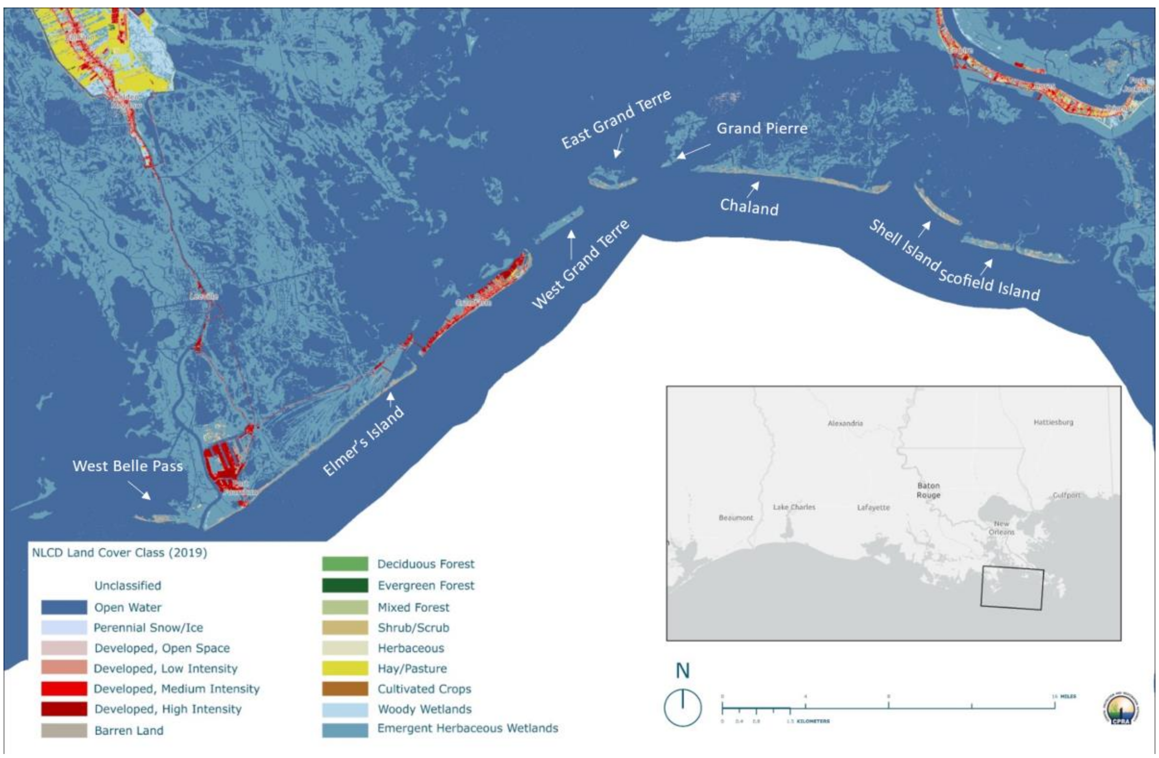

Figure 2. Map of the geographic location of the barrier islands, barrier spits, and headlands that were modified as part of the degraded barriers analysis.

In addition to the barrier island morphological evolution projections developed by the ICM-BI for Year 20, a simulated surface was created to approximate the condition of a degraded barrier island and headland system for the coastal region extending from West Belle Headland east to Scofield Island (Figure 2). This surface was developed for use in the ADCIRC simulations of storm surge and waves for the selected storms (Figure 1), under an exploratory scenario in which the barrier islands and headlands in this region of the coast were not restored and were instead allowed to degrade over time. The surface does not represent a specific time in the future, nor does it provide a projection of the configuration of the coastal system under a future environmental forcing. Instead, the degraded barrier island surface is intended to be an idealized – yet realistic – representation of the degraded state for each barrier island along the Caminada and Barataria regions.

The ICM-BI model includes simplified and parameterized representations of barrier island change and incorporates threshold-based auto-restoration (Dalyander et al., 2021) to capture the underlying assumption that the barrier island and headland system will be maintained. As such, the model does not include algorithms for accurately predicting the evolution of barrier islands once they become submerged, and thus, a modified approach was needed to develop the degraded barrier island surface. This approach consisted of:

1. Use ICM-BI to simulate the evolution of the Caminada and Barataria regions of the coast with parameters associated with a realistic representation of the future. The model used the lower SLR projection and model parameters were set as follows.
    a. Auto-restoration thresholds:
        i. Individual cross-shore profiles flagged as crossing the threshold for restoration when 90% of the subaerial width is lost (for barrier islands).
        ii. Individual cross-shore profiles flagged as crossing the threshold for restoration when the shoreline erodes past the dune crest (for headlands).
        iii. Restoration units are auto-restored when 50% of individual cross-shore associated with that unit are flagged as needing restoration.
    b. Cross-shore retreat rates at the start of the simulation reduced 10% from baseline values.
    c. Cross-shore retreat rates held constant over the entire period of simulation, with no increase with eustatic SLR.
    d. Subsidence and eustatic SLR included.
2. Extract the profiles for each barrier island and headland in the system from the ICM-BI output from the year just prior to the first auto-restoration (Table 1).
3. Using the ADCIRC Digital Elevation Model (DEM) corresponding to Year 20 as a base layer (“base DEM”), interpolate the ICM-BI degraded profiles to update the ADCIRC DEM, creating an “interim degraded DEM”.
4. Compare the base DEM with the interim degraded DEM. For all nodes where the elevation of the base DEM is above 2 meters (m) depth and the elevation of the

interim degraded DEM is lower than the elevation of the base DEM, update the elevation to be the value in the interim degraded DEM (Figure 3).

5. For all nodes in ADCIRC along the barrier dune crest that were above 0.5 m, the elevation was set to 0.5 m, to represent a degraded dune system. The resulting surface is the final degraded DEM (Figure 4).

The final two steps of the process are necessary because the ICM-BI profiles used to create the interim degraded DEM originate from different model years. Because cross-shore retreat takes place along the entire cross-shore extent of each profile within the ICM-BI, this creates alongshore discontinuities in the resulting DEM when the profiles are merged to form a single surface. This issue is mitigated by only updating the base DEM for the surf zone and subaerial portions of each barrier island and headland.

Table 1. Model output years used in creating a merged ICM-BI degraded barrier island surface. Profiles were extracted for each barrier island or headland (i.e., unit) for the year shown, which represents the most degraded the unit becomes prior to auto-restoration in the model.

UNIT	REGION	YEAR JUST PRIOR TO FIRST RESTORATION (I.E., MOST DEGRADATION)	NOTES
WEST BELLE PASS	CAMINADA	18	-
PORT FOURCHON	CAMINADA	20	-
CENTRAL CAMINADA	CAMINADA	19	-
ELMER'S ISLAND	CAMINADA	23	-
WEST GRAND TERRE	BARATARIA	52	NEVER RESTORES
EAST GRAND TERRE	BARATARIA	52	NEVER RESTORES
GRAND PIERRE	BARATARIA	35	-
CHALAND	BARATARIA	12	-
SHELL ISLAND	BARATARIA	19	-
PELICAN ISLAND	BARATARIA	22	-
SCOFIELD ISLAND	BARATARIA	22	-

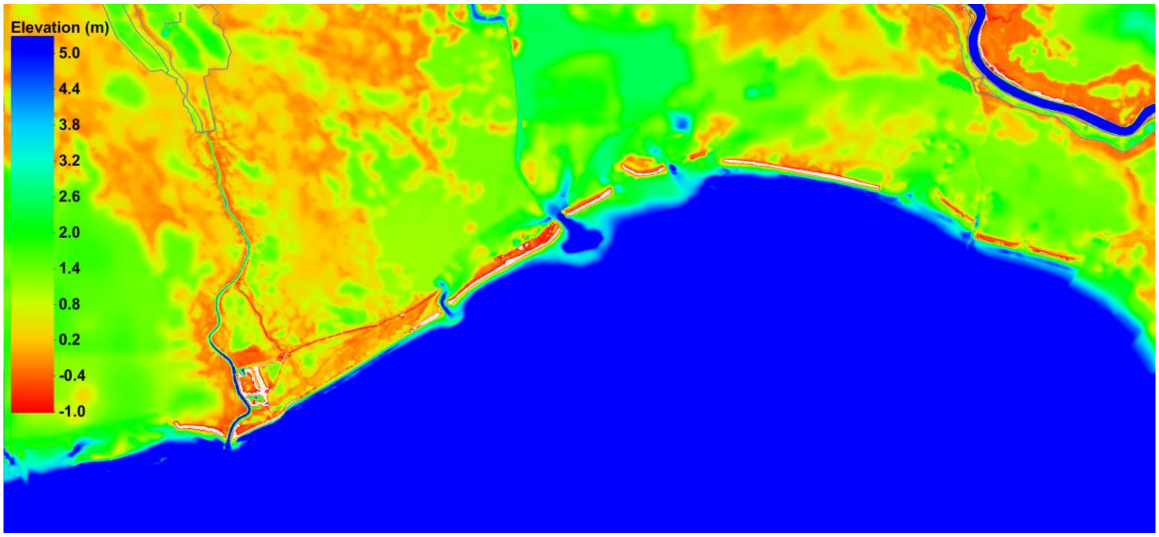

Figure 3. ADCIRC base DEM used in creating the degraded barrier island surface. This surface corresponds to Year 20 in the lower scenario.

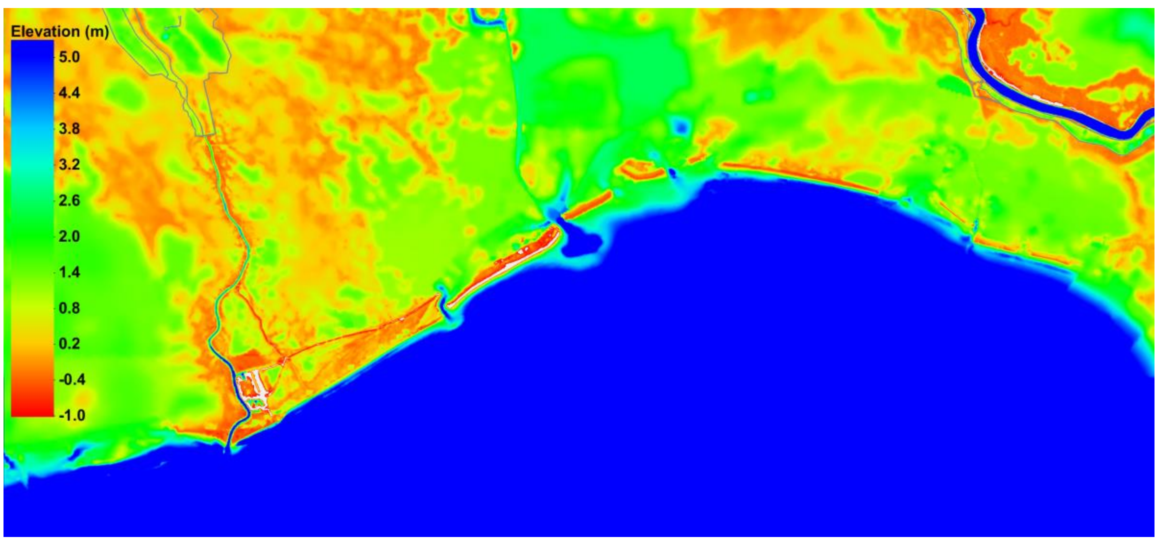

Figure 4. Final degraded barrier island DEM created through updating the elevations of the barrier islands and headlands of the base DEM (Figure 3) using output of the ICM-BI model.

3.0 MODEL OUTPUTS

3.1 STORM 66

Synthetic Storm 66 is a tropical storm with a track heading of approximately northwest (300 degrees), trending across west Louisiana approaching the Chenier Plain, making landfall near the Texas-Louisiana state boundary. The storm had a forward speed of 8 kts, a reference pressure deficit of 78 millibars (mb), and radius to maximum winds of 44.4 mi. This storm is one of the slower moving storms in the simulation matrix (Figure 5).

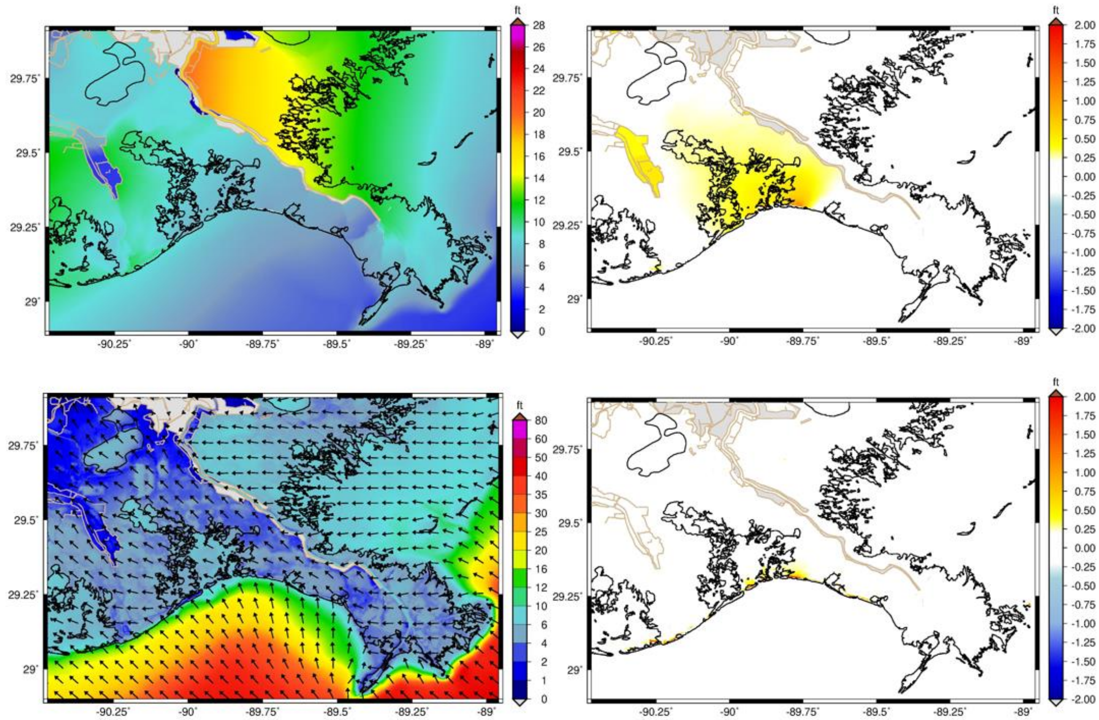

Figure 5. Peak water surface elevation (feet [ft], North American Vertical Datum of 1988 [NAVD88]; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 66 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 66 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION WITH DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the anticipated surge from Storm 66 in a FWOA with degraded barriers would be greatest to the east of the storm (Figure 5). While landfall would occur in southwest Louisiana in the Chenier Plain, simulations show that the highest peak water surface elevation levels are projected to occur in the upper Breton Sound Basin between Lake Borgne and the Mississippi River including the Biloxi Marshes, with maximum elevations occurring in Plaquemines Parish near the junction of these two levee systems. Other locations projected to experience notable water above surface include northern Terrebonne Bay, west-central Barataria Basin from Larose to Golden Meadow, and on the east bank of the Mississippi River in Plaquemines Parish south of the East Bank Federal Levees.

ADCIRC+SWAN simulations show that the highest expected peak water surface elevations, an estimated 18 to 20 ft, would be found in the upper Breton Sound Basin between Lake Borgne and the Mississippi River, an area that includes St. Bernard Parish and the portion of Plaquemines Parish located on the east bank of the Mississippi River. Projected water surface elevations are lower in the northern reaches of Terrebonne Bay (10 to 12 ft) and reach the same magnitude along Larose and Golden Meadow, lower Breton Sound Basin, and Biloxi Marshes (Figure 5). Comparisons between a FWOA with degraded barriers and a FWOA with restored barriers in Year 20 show that water surface elevations from Storm 66 would are projected to increase throughout Barataria Bay from 0.25 to 0.75 ft when barriers are degraded, most noticeably near Chaland Headland where the increase in surge height is expected to exceed 1 ft for at least 5 mi inland (Figure 5). ADCIRC+SWAN results do not identify notable changes in peak water surface elevations elsewhere in the domain under this scenario.

ADCIRC+SWAN results project offshore wave heights south of the modern Mississippi River Bird's Foot Delta ranging from 40 to 50 ft with a northwesterly direction, following the wind speed direction as Storm 66 approaches land (Figure 5). Model results show that wave heights are expected to attenuate along the central Louisiana coast before reaching the coastline in a FWOA with degraded barriers. From the Caminada Headland to Sandy Point, just west of the delta, waves are projected to attenuate to heights ranging from 12 to 16 ft. Greater reductions in wave height are projected in locations within the ebb-tidal deltas of Barataria Pass and the tidal inlets to the east through west of the Chaland Headland.

To the west of the Mississippi River in the Terrebonne and Barataria bays, ADCIRC+SWAN simulations show significant wave heights of less than 6 ft, but to the east of the river in Breton and Chandeleur sounds, the open coast allows for more wave transmission and local generation, resulting in wave heights of 6 to 10 ft (Figure 5). Differences in the wave heights between a FWOA with degraded barriers and a FWOA with restored barriers show an increase along the barrier shoreline of 0.25 ft. ADCIRC+SWAN results show the greatest projected change near Chaland Headland. Maximum projected wave heights ranging from 0.75 to 1 ft are expected in the immediate vicinity of the degraded Chaland Headland (Figure 5). Model results show minimal to no change in wave height in other basins from Storm 66 in a FWOA with degraded barriers.

3.2 STORM 80

Synthetic Storm 80 is a tropical storm with a track heading of approximately northwest (300 degrees), trending west of the Caminada Headland across Terrebonne Bay, making landfall south of Cocodrie, Louisiana. The storm had a forward speed of 9.3 kts, a reference pressure deficit of 78 mb, and radius to maximum winds of 48 mi. This is a large storm with a similar approach angle as Storm 66, although Storm 80 tracks closer to Barataria Basin than Storm 66.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 80 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC simulations show that the anticipated surge from Storm 80 would be greatest to the east of the storm (Figure 6). While landfall would occur in Terrebonne Bay near the town of Cocodrie, ADCIRC+SWAN simulations show that the highest water surface elevations are projected east of the Mississippi River in the upper and middle Breton Sound Basin, including the Biloxi Marshes. ADCIRC+SWAN simulations show that the highest expected water surface elevations, an estimated 20 to 24 ft, are expected between to occur between Lake Borgne and the Mississippi River near the junction of the Mississippi River levees and the Hurricane and Storm Damage Risk Reduction System (HSDRRS) levees. ADCIRC+SWAN simulations show slightly lower water surface elevations ranging from 18 to 20 ft in the Biloxi Marshes located between these levees and Breton Sound. On the west bank of the Mississippi River, lower water surface elevations approaching 12 ft are projected along the Mississippi River levees from New Orleans to Venice.

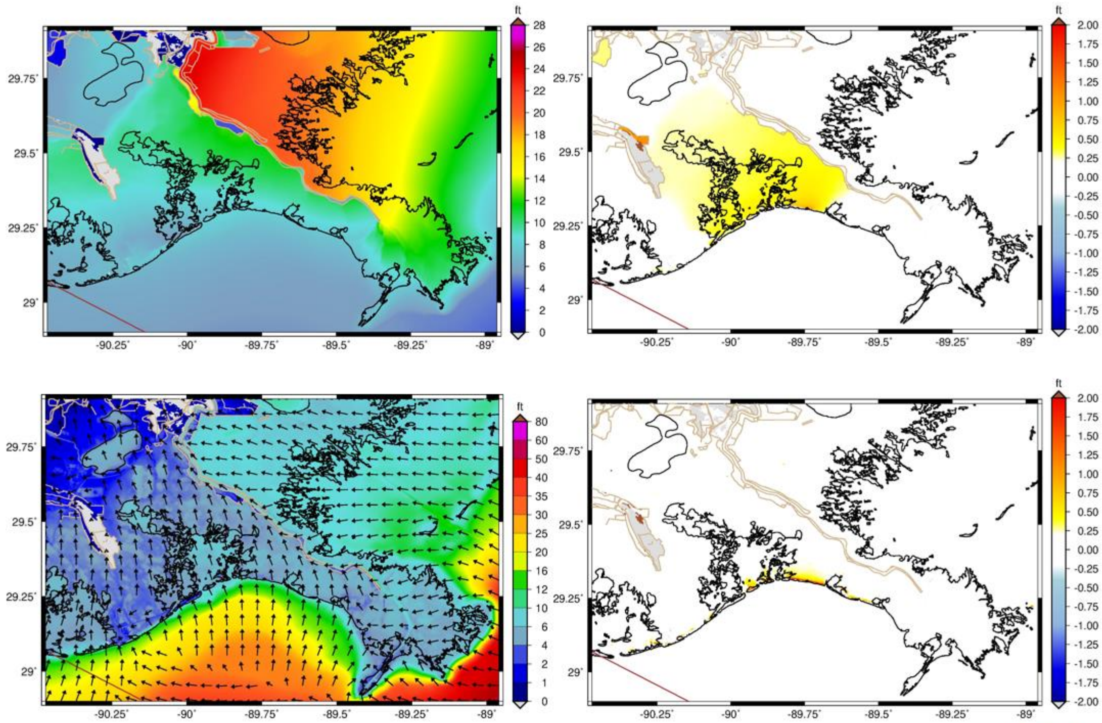

Figure 6. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 80 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN results show that the difference in water surface elevation resulting from Storm 80 in Year 20 in a FWOA with degraded barriers compared to a FWOA with restored barriers are projected to be greatest in the Barataria Bay and in the broader Barataria Basin north of Little Lake. In these locations, model results show increases of 0.25 to 0.75 ft in locations proximal to the eastern barrier islands, including Grand Pierre and the Chaland Headland. Inland of these barrier islands, increases of more than 1 ft are projected as far as 5 mi inland in a FWOA with degraded barriers (Figure 6). Beyond Barataria Basin, little to no notable changes in water surface elevation from Storm 80 in a FWOA with degraded barriers compared to a FWOA with restored barriers are observed in the model results.

Offshore wave heights resulting from Storm 80 are projected to approach 50 ft in locations south of the modern Mississippi River Bird's Foot Delta. ADCIRC+SWAN results show wave moving in a northerly direction as the storm tracks west of Barataria Bight following the local wind directions as the storm approaches land (Figure 6). Significant wave heights attenuate along the Louisiana coast both the Terrebonne Region and the Barataria Region before reaching the coastline. From the Caminada Headland to Sandy Point, just west of the Mississippi River Bird’s Foot Delta, ADCIRC+SWAN simulations show wave heights ranging from 12 to 16 ft. As the track of Storm 80 moves inland of the degraded barriers, significant wave heights of 6 to 10 ft are projected across Barataria Bay (Figure 6). Differences in the wave heights between a FWOA with degraded barriers and a FWOA with restored barriers are expected to range from 0.25 to 0.75 ft along the barrier shoreline, most notably from Grand Isle to the Chaland Headland and Shell Island (Figure 6). Projected changes in wave height from Storm 80 in a FWOA with degraded barriers relative to a FWOA with restored barriers are negligible beyond 1 mi of the barrier shoreline, except for locations inland of Chaland Headland, where ADCIRC+SWAN results show results persisting for up to 2 mi inland.

3.3 STORM 178

Synthetic Storm 178 is a tropical storm with a track heading of approximately northwest (320 degrees), trending west of the modern Mississippi River Delta near the terminus of Southwest Pass, crossing the Barataria Bight, and making landfall east of Grand Isle at West Grand Terre Island, Louisiana. The storm had a forward speed of 7.7 kts, a reference pressure deficit of 88 mb, and radius to maximum winds of 39.1 mi. This storm is also slow moving storm with a track that tracks across the center of Barataria Basin along the estuarine axis.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 178 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana’s 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the anticipated surge from Storm 178 in a FWOA with degraded barriers would be greatest to the east of the storm (Figure 7). While landfall would occur near Grand Isle and West Grand Terre Island, model simulations show that the highest water surface elevations are projected to occur in the upper and middle Breton Sound Basin, included much of the Biloxi Marshes. Simulations show an estimated 20 to 24 ft of water surface elevation resulting from Storm 178 at the junction of the Mississippi River levees and the HSDRRS levees between Lake Borgne and the Mississippi River, where ADCIRC+SWAN results show water piling against the levees. In the Biloxi Marshes to the east of the levees, lower but still notable water surface elevations of 18 to 20 ft are projected. On the west bank of the Mississippi River, ADCIRC+SWAN results project water surface elevations of 10 to 12 ft along the Mississippi River levees from Myrtle Grove to Venice.

Projected differences in water surface elevations from Storm 178 between a FWOA with degraded barriers and a FWOA with restored barriers in Year 20 shows increases to the east of the storm, landward of Chaland Headland and Scofield Island. ADCIRC+SWAN simulations show an average increase in water surface elevation ranging from 0.25 to 0.5 ft proximate to these islands, reaching as high as 0.75 ft landward of the Chaland Headland. Model results project increases in water surface elevation from Storm 178 in a FWOA with degraded barriers in Year 20 of up to 0.5 ft will be experienced up to 8 mi inland, reaching the marshes and bays immediately south of Port Sulphur (Figure 7). ADCIRC+SWAN results show little influence of degraded barriers on the impacts of Storm 178 outside the Barataria Basin in a FWOA in Year 20.

In Year 20, offshore wave heights resulting from Storm 178 in a FWOA with degraded barriers are projected to reach 50 ft to the south of the Mississippi River Delta. ADCIRC+SWAN results show waves moving in a northwesterly and northeasterly direction driven by local winds on either side of the storm track as the storm transits Barataria Bight and approaches land (Figure 7). Significant wave heights attenuate along the Louisiana coast before reaching the coastline. From the Caminada Headland to Sandy Point, just west of the Mississippi River Delta, model results show wave heights ranging from 10 to 12 ft with higher attenuation levels located around the ebb-tidal deltas of Barataria Pass and the tidal inlets west of the Chaland Headland. ADCIRC+SWAN results show wave heights of 4 to 6 ft throughout Barataria Bay inland of these barrier islands. To the east of the Mississippi River, the open coast in the Breton and Chandeleur sounds allows for more wave transmission and more local generation, resulting in project wave heights of 6 to 10 ft.

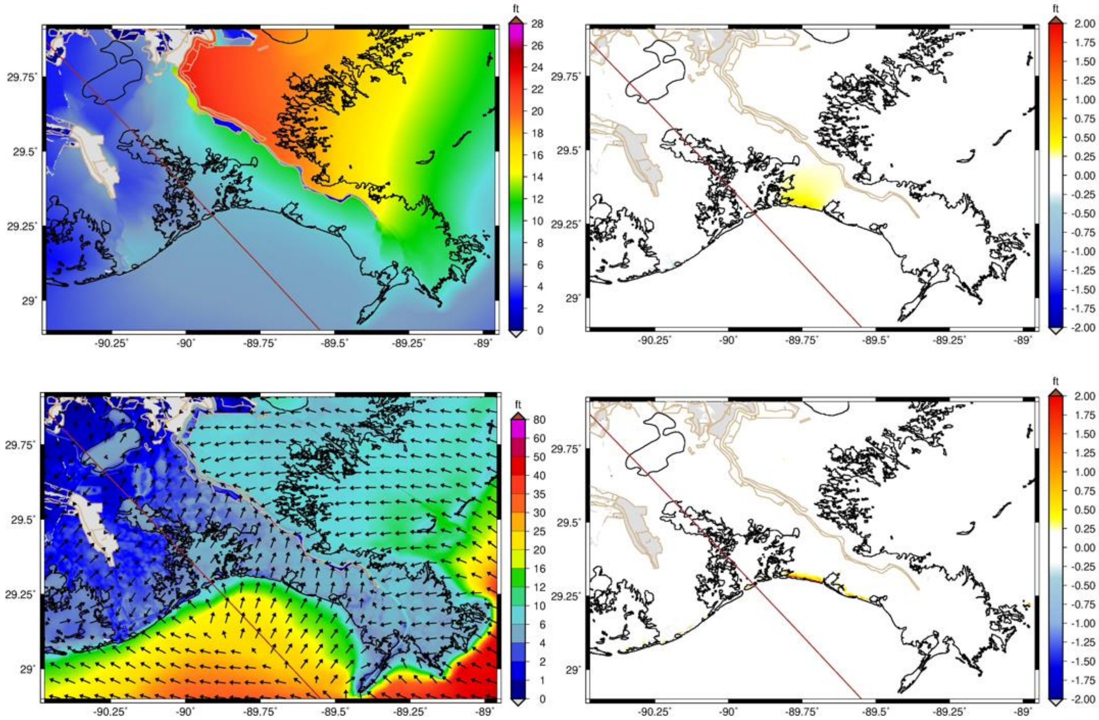

Figure 7. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 178 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN simulations for Storm 178 project that wave heights between a FWOA with degraded barriers will be approximately 0.25 ft along the barrier shoreline relative to wave heights observed in a FWOA with restored barriers. However, projected change near Chaland Headland, Shell Island and Scofield Island are projected to range from 0.25 to 0.75 ft with the highest levels expected in the immediate vicinity of the degraded Chaland Headland (Figure 7). ADCIRC+SWAN results show that little to no notable change is observed beyond 1 mi of the barrier shoreline in a FWOA with degraded barriers compared to a FWOA with restored barriers in Year 20.

3.4 STORM 268

Synthetic Storm 268 is a tropical storm with a track heading of approximately north to northwest (340 degrees), trending across the Marsh Island, in Atchafalaya Bay. The storm crosses Cypremort Point and crosses Vermilion Bay before making landfall near Avery Island, Louisiana. The storm had a forward speed of 10.2 kts, a reference pressure deficit of 78 mb, and radius to maximum winds of 29.5 mi. This storm, and Storm 66 are the only two storms considered that make landfall west of the Teche Delta.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 268 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the projected water surface elevations resulting from Storm 268 in a FWOA with degraded barriers would be greatest to the east of the storm (Figure 8). While landfall would occur in Vermilion Bay near Avery Island, simulations show that the highest surge levels are projected to occur in two primary locations. The first in the upper Breton Sound Basin between Lake Borgne and the Mississippi River, an area that includes St. Bernard Parish and the portion of Plaquemines Parish located on the east bank of the Mississippi River. ADCIRC+SWAN simulations project an estimated 8 to 12 ft of water above surface in this location. The second location identified by ADCIRC+SWAN simulations in northeastern Terrebonne Bay west of the Larose to Golden Meadow levee system. Water surface elevations of 8 to 12 ft from Storm 268 in a FWOA with degraded barriers are project for this location in Year 20. ADCIRC+SWAN results show lower but still notable water surface elevations of 7 to 9 ft through central Barataria Basin, including locations south of the Larose to Golden Meadow levee system along the west bank of the Mississippi River in Plaquemines Parish between Live Oak and Grand Bayou (Figure 8).

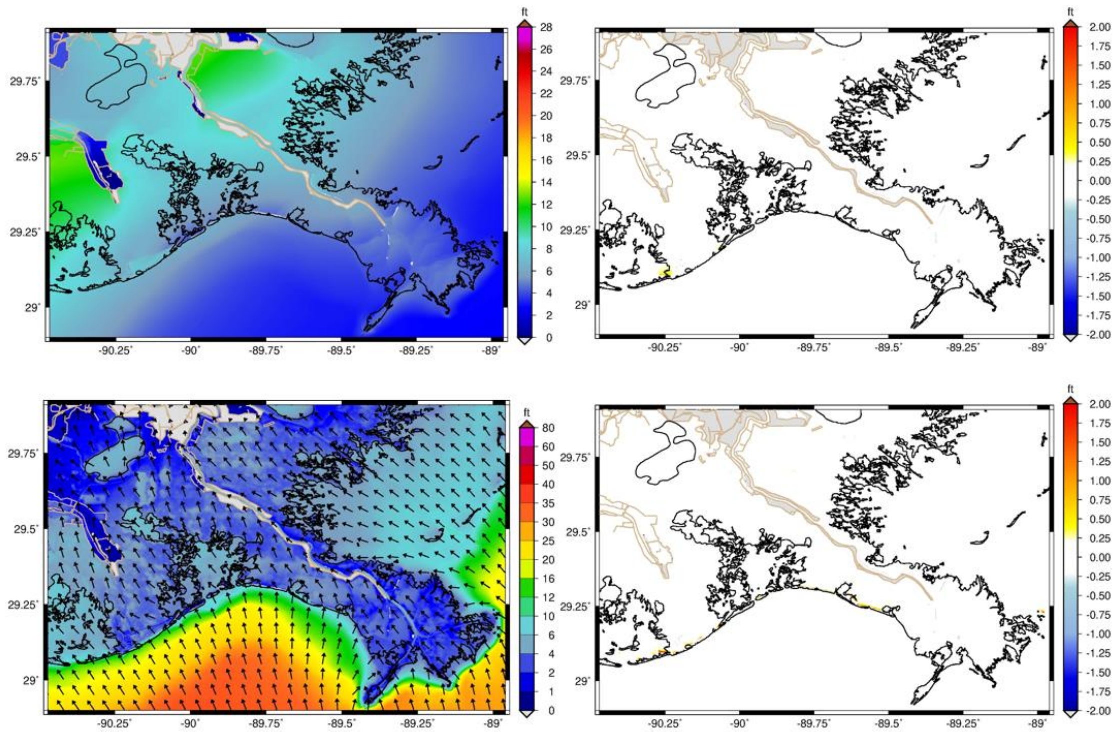

Figure 8. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 268 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN simulations of Storm 268 in Year 20 show little to no notable difference in water surface elevations between a FWOA with degraded barriers and a FWOA with restored barriers. Minor changes of 0.5 ft or less are observed near West Belle Pass. However, the influence of these water surface elevation changes is projected to be local.

Offshore wave heights resulting from Storm 268 are predicted to approach 40 ft south of the modern Mississippi River Bird's Foot Delta with a northerly direction toward the delta and across Barataria Bight (Figure 8). ADCIRC+SWAN results show that wave heights are expected to attenuate before reaching the coastline. From the Caminada Headland to Sandy Point, located just to the west of the Mississippi River Delta, ADCIRC+SWAN results show wave heights of 10 to 12 ft. These wave heights are projected to decrease further around the ebb-tidal deltas of Barataria Pass and the tidal inlets to the east up to Chaland Headland. Inland of the barrier islands, in Barataria Bay, wave heights of 6 to 10 ft are projected.

ADCIRC+SWAN simulations of Storm 268 in Year 20 project that the greatest difference in wave heights between a FWOA with degraded barriers and a FWOA with restored barriers would occur immediately adjacent to the barrier shoreline, where the average observed increase is from 0.25 to 0.5 ft. The highest projected change is expected to occur near West Belle Pass and Scofield Islands, where wave heights increases of approximately 0.75 ft are projected to extend from the barrier island inland for 1 mi (Figure 8).

3.5 STORM 289

Synthetic Storm 289 is a tropical storm with a track heading of approximately north to northwest (340 degrees), trending west of the modern Mississippi River Delta, crossing the Barataria Bight, and making landfall west of the Chaland Headland. The storm had a forward speed of 8.8 kts, a reference pressure deficit of 78 mb, and radius to maximum winds of 23.9 mi.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 289 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that water surface elevations resulting from Storm 289 in a FWOA with degraded barriers are projected to be greatest to the east of the storm (Figure 9). While landfall would occur west of Chaland Headland, model simulations show that the highest water surface elevations are projected to occur in the upper and central Breton Sound Basin. In the upper basin, ADCIRC+SWAN simulation project an estimated 16 to 18 ft between Lake Borgne and the Mississippi River adjacent to the Mississippi River levees and the HSDRRS levees. In the central Breton Sound Basin, water surface elevations ranging from 14 to 16 ft are projected in the Biloxi Marshes near Eloi Bay. Peak water surface elevations in the eastern Barataria Basin along the Mississippi River west back levees project to approach 12 ft from Empire to Venice and 10 ft from Empire to Grand Bayou.

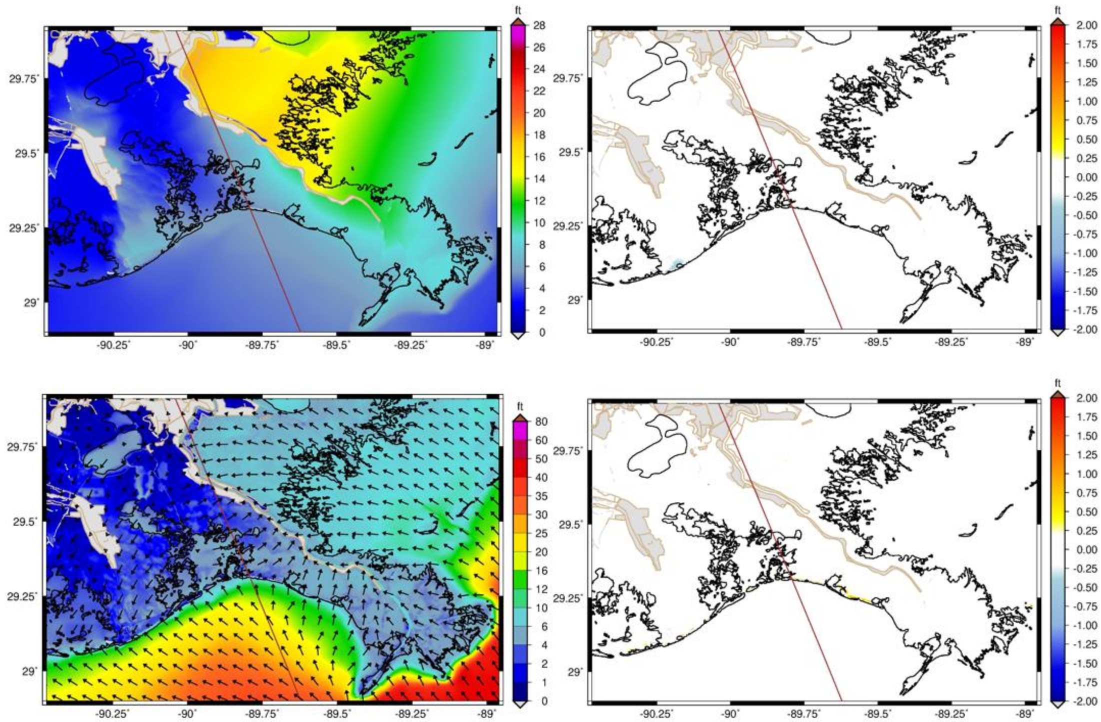

Figure 9. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 289 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN simulations show that little to no notable differences in water surface elevation are projected between a FWOA with degraded barriers and a FWOA with restored barriers, with the exception of a small reduction in water surface elevation of 0.5 ft east of West Belle Pass (Figure 9).

Offshore wave heights in Year 20 resulting from Storm 289 in a FWOA with degraded barriers are projected to approach 50 ft south of the modern Mississippi River Bird's Foot Delta. ADCIRC+SWAN results show the waves moving in a northwesterly direction toward the modern delta and across Barataria Bight, following the local wind direction as the storm approaches land (Figure 9). Peak wave heights along the Barataria barrier shoreline are similar to the results observed in other storm simulations, with heights ranging from 10 to 16 ft. Throughout Barataria Bay inland of the barriers, ADCIRC+SWAN simulations show projected wave heights of 6 to 10 ft in Year 20 in a FWOA with degraded barriers.

There is little observed difference in wave heights resulting from Storm 289 in Year 20 between a FWOA with degraded barriers and a FWOA with restored barriers in the ADCIRC+SWAN results. Simulations project local wave height increases on the order of 0.25 to 0.5 ft immediately adjacent to the Chaland Headland and Scofield Island. These changes become negligible less than a mile landward of the barrier shoreline.

3.6 STORM 395

Synthetic Storm 395 is a tropical storm with a track heading of approximately north to northwest (340 degrees), trending across the central Louisiana coast, across the western Terrebonne Bay east of the Isles Dernieres, and making landfall between Cocodrie and Chauvin, Louisiana. The storm had a forward speed of 11.4 kts, a reference pressure deficit of 88 mb, and radius to maximum winds of 18.6 mi. This storm is one of the two smaller storms examined in this analysis.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 395 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the anticipated water surface elevation from Storm 395 in a FWOA with degraded barriers would be greatest to the east of the storm (Figure 10). While landfall would occur west of Terrebonne Bay near Cocodrie, LA, model simulations project highest peak water surface elevations would occur at several locations in the Terrebonne and Barataria regions. In the Terrebonne Region, model results project high water surface elevations along the barriers fronting Terrebonne Bay and to the west of the Larose to Golden Meadow levee system in Lafourche Parish. At the eastern edge of the Barataria Region, high peak water surface elevations are projected on the west bank of the Mississippi River from Lafitte to Port Sulphur. ADCIRC+SWAN simulations project an estimated 10 to 12 ft of water above surface in all of these locations. Other areas projected to experience high water surface elevations in Year 20 from Storm 395 in a FWOA with degraded barriers, include the lower Breton Sound, the central Barataria Basin, the lower Mississippi River from

Empire to Venice, and the Caminada Headland. ADCIRC+SWAN simulations project anywhere from 7 to 9 ft of water above surface in each of these locations.

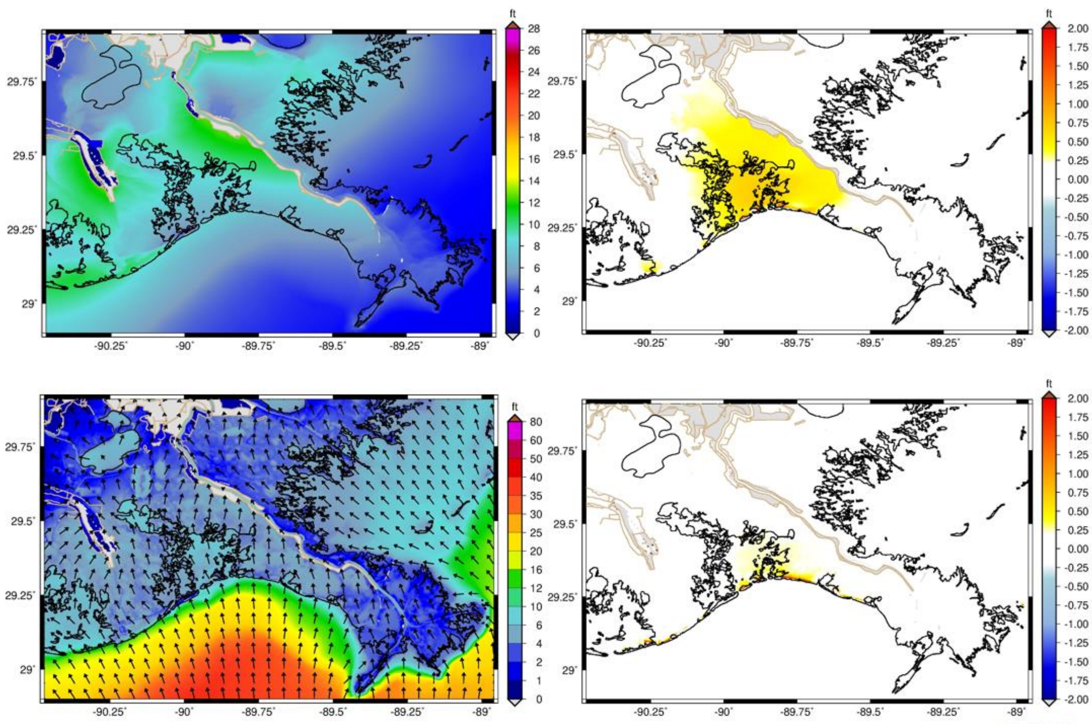

Figure 10. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 395 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN results for Storm 395 in Year 20 project widespread differences in water surface elevations between a FWOA with degraded barriers and a FWOA with restored barriers throughout Barataria Basin, with a much larger footprint than the other synthetic storms evaluated here. Model results project water surface elevation increases in Barataria Bay ranging from 0.75 to 1.25 ft. Along the Mississippi River at the eastern rim of Barataria Basin, Storm 395 is projected to result in 0.25 to 0.5 ft of additional water surface elevation in a FWOA with degraded barriers relative to a FWA with restored barriers between Lafitte and Myrtle Grove. ADCIRC+SWAN results project an additional 0.5 to 0.75 ft of water above surface near Empire in lower Plaquemines Parish.

Offshore wave heights resulting from Storm 395 are projected to approach 30 ft just south of the modern Mississippi River Bird's Foot Delta with the waves moving in a northerly direction toward the delta. ADCIRC+SWAN simulations also show wave heights as high as 35 ft across Barataria Bight, propagating in the same northerly direction (Figure 10). Projected wave heights along the Barataria barrier shoreline range from 10 to 16 ft while in Barataria Bay, inland of the barrier shoreline, projected wave heights range from 6 to 10 ft.

ADCIRC+SWAN simulations project that the difference in wave heights between a FWOA with degraded barriers and a FWOA with restored barriers are greatest in locations proximal to the barrier shoreline, extending up to ten miles inland (Figure 10). Model results show that wave heights increase from 0.75 to 1.25 ft near West and East Grande Terre, Chaland Headland and along Shell, Pelican, and Scofield Islands; the wave height increase is local, and diminishes within 1 mi from the barrier, except for Barataria Bay, where wave heights increase of the order of 1.25 ft extends throughout the Bay. Finally, wave height increases of 0.25 to 0.5 ft are evident throughout the backbarrier of Chaland Headland, in Bastian Bay, and throughout most of eastern Barataria Bay up to Bay Baptiste (Figure 10).

3.7 STORM 505

Synthetic Storm 505 is a tropical storm with a track heading of approximately north to northwest (340 degrees), trending across the central Louisiana coast, passing east of Isles Dernieres across central Terrebonne Bay, making landfall south of Larose, Louisiana. The storm had a forward speed of 6.3 kts, a reference pressure deficit of 118 mb, and radius to maximum winds of 15.9 mi. Storm 505 is the slowest of the storms evaluated; it is also both the most intense, and the smallest in size from the storms evaluated.

SURGE AND WAVES

The expected storm surge and wave heights in Year 20 from Storm 505 in a FWOA with degraded barriers and a FWOA with restored barriers were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the projected peak water surface elevation from Storm 505 would be greatest to the east of the storm (Figure 11). While landfall would occur east of Terrebonne Bay south of the Larose to Golden Meadow levee system, simulations show that the highest water surface levels would occur along the barriers fronting Terrebonne Bay and along the west bank of the Mississippi River from Myrtle Grove to Port Sulphur, with projected water surface elevations ranging from 14 to 16 ft. ADCIRC+SWAN simulations project slightly lower water surface elevations further upriver from Empire to Westwego, where 10 to 14 ft of water above surface is observed. Similar water surface elevations are projected for the western edge of the Barataria Basin from Golden Meadow to Lockport. Projected water surface elevations in the lower Barataria Basin along the barrier shoreline and up to 5 mi inland range from 8 to 10 ft. To the west of the Mississippi River Delta, at the junction of the Mississippi River levees and the HSDRRS levees near the community of Braithwaite, projected water surface elevations resulting from Storm 505 in a FWOA with degraded barriers are similar to those observed closer to the location of landfall, ranging from 14 to 16 ft.

ADCIRC+SWAN simulations for Storm 505 in Year 20 show that expected differences in water surface elevation between a FWOA with degraded barrier and a FWOA with restored barriers are widespread throughout Barataria Basin. The large spatial footprint of projected change is expected to be similar to that of Storm 395. Water surface elevations are projected to increase in Barataria Bay upwards of 1.25 ft while locations to the west of the Mississippi River, including Lafitte, Myrtle Grove, and Port Sulphur are projected to experience 0.25 to 0.5 ft of additional water surface elevation from Storm 505 in a FWOA with degraded barriers in Year 20. However, further downriver, ADCIRC+SWAN simulations show appreciably higher increases in water surface elevation near Grand Bayou, with values ranging from 1.5 to 2 ft.

Offshore wave heights resulting from Storm 505 in Year 20 are projected to approach 30 ft south of the modern Mississippi River Bird’s Foot Delta, with waves moving in a northerly direction toward the delta. ADCIRC+SWAN results project greater wave heights across Barataria Bight ranging from 30 to 35 ft, propagating in the same northerly direction (Figure 11). Projected wave heights along the Barataria barrier shoreline are similar to previous storms, ranging from 10 to 16 ft. Throughout Barataria Bay, ADCIRC+SWAN simulations project waves from 6 to 10 ft in height.

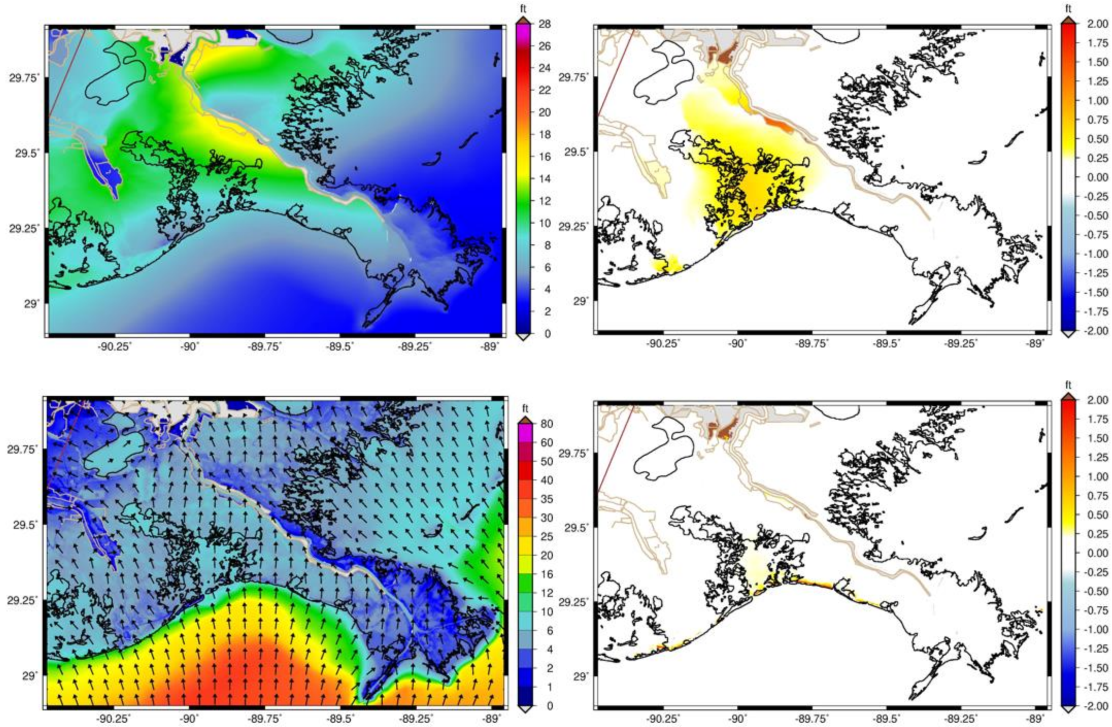

Figure 11. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 505 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

ADCIRC+SWAN results projected for Storm 505 in Year 20 show that differences in wave heights between a FWOA with degraded barriers and a FWOA with restored are greatest in locations proximal to the barrier shoreline, where projected wave height increases in a FWOA with degraded barriers range from 0.25 to 0.75 ft (Figure 11). Model results show similar increases extending up to 1 mi inland of the barrier shoreline. Finally, ADCIRC+SWAN simulation show wave heights within the lower Barataria Bay inland of the barriers increasing approximately 0.25 ft and extending up to 3 mi inland of the bay.

3.8 STORM 590

Synthetic Storm 590 is a tropical storm with a track heading of approximately northeast (40 degrees). The storm enters Terrebonne Bay between the Isles Dernieres and the Timbalier Islands before making landfall west of Golden Meadow. The storm has a forward speed of 16.1 kts, a reference pressure deficit of 68 mb, and radius to maximum winds of 28.5 mi. Storm 590 is the fastest moving of storms evaluated, is comparatively the least intense, and has an average size compared to all other storms evaluated.

SURGE AND WAVES

The expected storm surge and wave heights from Storm 590 initial and future conditions were simulated using the ADCIRC+SWAN model. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. The ADCIRC+SWAN model version used in this work is v55.00 and represents the latest available enhancements to the model formulations at the time that the study was conducted.

FUTURE WITHOUT ACTION DEGRADED BARRIER (YEAR 20)

The lower scenario was used to project storm impacts for Year 20 conditions. Under this scenario, ADCIRC+SWAN simulations show that the anticipated water surface elevation resulting from Storm 590 in Year 20 in a FWOA with degraded barriers would be greatest to the east of the storm (Figure 12). While landfall would occur along Terrebonne Bay west of Golden Meadow, simulations show that the highest peak water surface elevation levels would occur along the barriers fronting Terrebonne Bay as well as along the eastern Barataria Basin along the levees located on the west bank of the Mississippi River extending from Myrtle Grove to Venice. Simulations show an estimated 14 to 16 ft of water above surface would be found between Diamond and Empire. ADCIRC+SWAN results show slightly lower water surface elevations of 10 to 12 ft in the backbarrier of eastern Barataria Basin, from Bay Batiste to Bay Pomme d'or. Along the barrier shoreline in the lower Barataria Basin, Storm 590 is projected to result in 8 to 10 ft of water surface elevation along the barrier shoreline in Year 20 of a FWOA with degraded barriers. The water surface elevations are projected to extend up to 2 mi inland.

Projected differences in water surface elevation from Storm 590 in Year 20 between a FWOA with degraded barriers and a FWOA with restored barriers are widespread throughout Barataria Bay and the southeastern Barataria Basin. ADCIRC+SWAN results show that Storm 590 will have a similar footprint to Storms 395 and 505. In a FWOA with degraded barriers, water surface elevations are projected to increase in Barataria Bay anywhere from 0.75 to 1 ft. Along the west bank of the Mississippi River, model simulations project a lower magnitude of change ranging from 0.25 to 0.5 ft from Myrtle Grove to Empire with similar values projected west to the barrier shoreline. ADCIRC+SWAN results also project a small increase in water surface elevation in the backbarrier of West Belle Pass, but the impacts are not expected to be widespread.

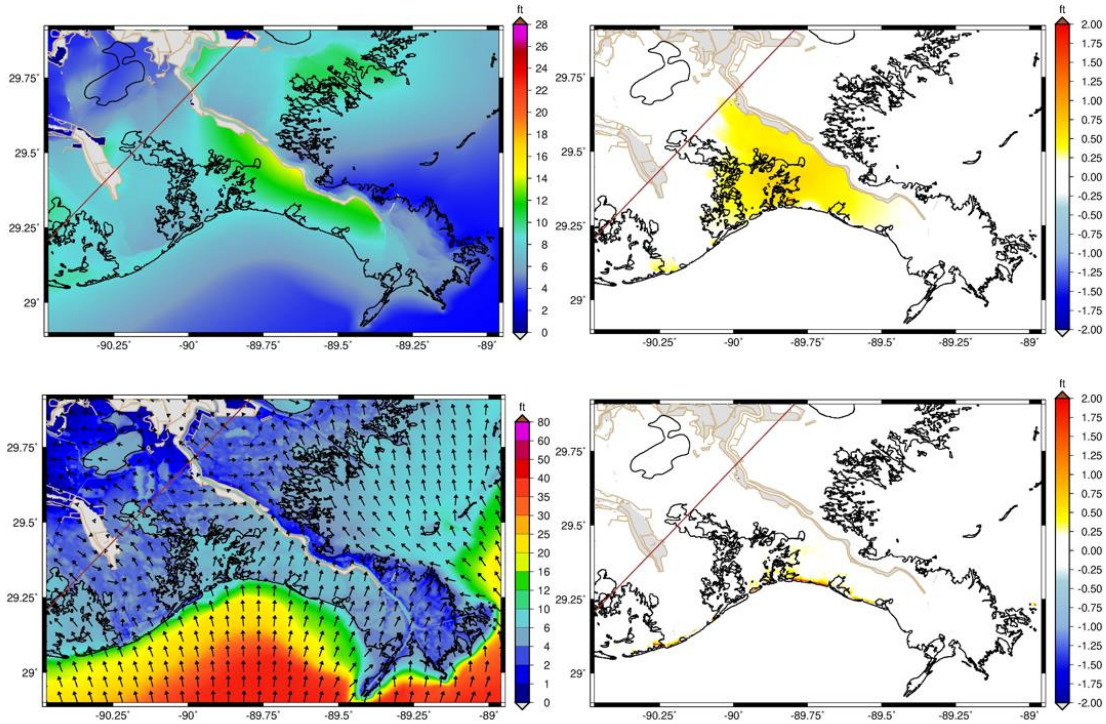

Figure 12. Peak water surface elevation (ft, NAVD88; top left) and significant wave heights (ft, NAVD88; bottom left) along the south-central Louisiana coast for Storm 590 in a FWOA with degraded barriers, simulated in the lower scenario in Year 20. The right panels show the difference in peak water surface elevation (top right) and the difference in significant wave heights (bottom right) between a FWOA with degraded barriers and a FWOA with restored barriers, respectively.

Offshore wave heights resulting from Storm 590 in Year 20 of a FWOA with degraded barriers are projected to approach 40 ft to the south of the modern Mississippi River Bird's Foot Delta with waves moving in a northerly direction toward the delta (Figure 12). ADCIRC+SWAN simulations project slightly lower wave heights of 30 to 35 ft across Barataria Bight, propagating in the same northerly direction. Projected wave heights along the Barataria Barrier shoreline range from 10 to 16 ft, with higher waves projected along the Caminada Headland and Elmer's Island, and along Chaland Headland to Scofield Island. Throughout Barataria Bay, inland of the barrier shoreline, model results project wave heights of 6 to 10 ft. ADCIRC+SWAN results project similar wave heights along the west bank of the Mississippi River from Grand Bayou to Venice.

ADCIRC+SWAN simulations of Storm 590 in Year 20 show increased wave heights ranging from 0.25 to 0.75 ft along the entire barrier shoreline in a FWOA with degraded barriers relative to a FWOA with restored barriers. This increase in wave height is expected to extend up to 1 mi inland. ADCIRC+SWAN simulations project greater increases in wave height of approximately 1 ft along Chaland Headland with these heights expected to extend 2 mi inland. While wave height increases of 0.25 ft or lower are projected for locations directly behind the barrier fronting Barataria Bay, the impacts of these increases are relatively localized.

4.0 REFERENCES

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